WISCONSIN DEPARTMENT OF NATURAL RESOURCES

RESEARCH REPORT 169

June 1995

Stunted Northern Pike: A Case History of Community Manipulations and Field Transfer

by **Terry L. Margenau**
Bureau of Research, Spooner

Abstract

Community manipulations were conducted to improve the growth and size structure of a stunted northern pike population in Island Lake, Washburn County. Manipulations included removal of small northern pike, bullhead, and bluegill, and stocking of white sucker and walleye. Over a period of 8 years the northern pike population in Island Lake showed no positive response to manipulations. Lack of response may have been the result of ineffective efforts to remove a large portion of the resident northern pike population. Diet information suggested northern pike may not have had adequate numbers of appropriate size and types of food items. Northern pike transferred from Island Lake to Largon Lake grew well and improved in condition. Indexing of forage in Largon Lake indicated an abundance of potential food items in the 6 to 8-inch size range. While field transfer of stunted northern pike was successful, management guidelines are recommended for the wise use of this as a management tool.

Contents

Introduction, 1

Study Lakes, 2

Methods, 3

- Community Manipulations, 3
- Northern Pike Response, 4
- Abundance of Other Species, 5

Results, 5

- Northern Pike Response, 5
- Other Species, 8

Discussion, 9

Management Implications, 11

Literature Cited, 12

T. MARGENAU

Stunted northern pike are undesirable for sport anglers.

Introduction

Northern pike, *Esox lucius*, is an important sport fish species in many midwestern lakes. However, in some of these waters northern pike become stunted. Stunting has been defined as a reduction in juvenile growth and near cessation of growth in adulthood (Diana 1987). Stunting of northern pike results in a size structure which is undesirable to anglers.

Management actions to increase growth rates of stunted fish populations such as removal and/or introduction of predators have been suggested (Noble 1980, Goeman et al. 1990) but are relatively untested for northern pike. Lowering the density of a predator population could potentially reduce inter- and intra-specific competition resulting in improved growth and size structure. In one Minnesota lake, Goeman and Spencer (1992) were unsuccessful in lowering densities or improving growth by removing small northern pike.

The relocation (field transfer) of northern pike removed from a stunted population also deserves management attention. Field-transferred fish may resume normal growth under suitable environmental conditions and contribute to the sport fishery. In addition, field transfers may reduce demands for cultured fish for stocking. However, consideration must be given to transfer of disease, loss of genetic fitness, and effects on the lake ecosystem as a result of new introductions.

The objectives of this study were to provide case history information on the response of a stunted northern pike population to community manipulations which include removal of small northern pike, centrarchid panfish (*Lepomis* spp.), and bullhead (*Ictalurus* spp.) and introductions of white sucker (*Catastomus commersoni*) and walleye (*Stizostedion vitreum*). Secondary objectives were to monitor the growth response of field-transferred northern pike from a stunted population. These results may help develop hypotheses for further testing regarding the applications for community manipulations and field transfers of stunted northern pike.

Figure 1. *Location of Island and Largon lakes within the St. Croix River drainage basin.*

Study Lakes

Island and Largon lakes are located in northwest Wisconsin within the St. Croix River (minor basin) and Mississippi River drainage (Fig. 1). Island Lake is a 276-acre seepage lake with a maximum depth of 44 ft and mean depth of 14 ft. Island Lake has a history of having an abundant population of stunted northern pike. A fish management survey in October 1984 noted the northern pike to be in "poor condition" and found mean length of northern pike at age 5 to be 17.2 inches (DNR, unpublished data). Largon Lake is a 129-acre seepage lake with a maximum depth of 10 ft and a mean depth of 6 ft. Northern pike growth in Largon Lake is good, with fish averaging 23.8 inches at age 5 (DNR, unpublished data). Largon Lake historically experienced frequent partial winterkills until 1977 when it was treated with rotenone and an aeration system was installed. Restocked species included northern pike, largemouth bass, and bluegill. Northern pike did well after the reclamation; however, apparent declines in numbers prompted a survey in 1988. The 1988 survey suggested that the decline of northern pike was possibly the result of limited natural reproduction and recommended stocking fingerlings or disease-free transfer fish from other lakes.

NWD AERONAUTICS

Island Lake, Washburn County.

Table 1. *Community manipulations in Island Lake, Washburn County, 1986-92.*

Year	Northern Pike Removal (lb) (number)	White Sucker Introduction (lb) (number)	Bullhead Removal (lb)	Bluegill Removal (number)	Walleye Introduction (number) (length in inches)	
1986	NR[a]	0	1,950	NR	0	–
1987	NR	0	370	5,047[b]	16,700	(3-5)
					350	(9-13)
1988	NR	0	280	NR	12,700	(1-3)
					420	(15)
1989	86 (125)	1,550[c] (3,400)	277	NR	14,300	(3)
					2,800	(7)
1990	90 (320)	0	NR	NR	17,000	(3)
					1,800	(7)
1991	51 (170)	0	NR	NR	2,300	(10)
1992	NR	0	NR	NR	8,300	(4-7)

[a] No removal.
[b] Number <6 inches in 1986 and 1987.
[c] Mean length 10.4 inches.

Methods

Community Manipulations

During the study, 5 separate manipulations were performed in Island Lake (Table 1): (1) Northern pike (<18 inches) were removed from 1989 through 1991 during the spring spawning period and field transferred to Largon Lake. A total of 615 northern pike <18 inches (mean length and weight of 14.3 inches and 9.1 oz, respectively) was removed from Island Lake. Number of fish removed annually ranged from 125 to 320 (0.5-1.2/acre). (2) White suckers were stocked in March 1989 to provide supplementary forage for northern pike and to develop a spawning population. White suckers were introduced at 12.3/acre (5.6 lb/acre) with a mean size of 10.4 inches (SD = 1.31). (3) A total of 2,880 lb (10.5 lb/acre) of bullhead was removed from 1986 through 1989. (4) Panfish (primarily bluegill, *Lepomis macrochirus*) were removed during 1986 and 1987. A total of 5,047 bluegill (<6 inches) were removed. (5) Walleye fingerlings and yearlings (3-15 inches) were stocked from 1987 through 1992. The 3 latter manipulations (bullhead and panfish removal and walleye stocking) were done as part of a management project to improve the size structure of the panfish population and are not discussed in detail in this report.

T. MARGENAU

Northern pike < 18 inches were removed from Island Lake and transferred to Largon Lake.

Northern Pike Response

Island Lake

Northern pike were monitored for changes in population size structure, abundance, mortality, growth, and relative weight (W_r). Northern pike diet was also quantified. Northern pike were sampled in Island Lake 1985 through 1992 during the spring spawning season using fyke nets. All sampled fish were sexed, measured to the nearest 0.1 inch total length, and weighed to the nearest ounce. Several scales were removed from a subsample of the captured fish (10 samples/inch group/sex) for determining age. All fish handled were also marked with a fin clip and/or an individually numbered anchor tag for later identification. Total mortality rates were computed using catch curves from spring samples, and W_r calculated from a standard length-at-weight equation (Willis 1989). Comparisons for size structure and mortality rates used data from all sample years (1985-92), whereas population abundance, growth, and W_r focused on a subsample of the data (1986 and 1987, 1991 and 1992).

Abundance of northern pike (≥14.0 inches) in Island Lake was estimated with the Bailey modification of the Peterson formula (Ricker 1975). Fish handled during the spring spawning period made up the marking period and a combination of electrofishing, gill netting, and fyke netting shortly after the spawning period made up the recapture period.

Growth changes in northern pike were measured using length-at-age analysis. Acetate scale impressions were aged with a microfiche projector and summarized with FishCalc (Missouri Department of Conservation 1989).

Food items of northern pike in Island Lake were sampled during 1986-90. Northern pike were sampled at least once a month from May through October using a bow-mounted AC electrofishing boat. Stomach contents were flushed with pulsed gastric lavage (Foster 1977). Contents were preserved in jars containing a 5% formalin solution in the field and then transported to the lab for later identification and measurement (total length and weight). When digestion had progressed too far to get an accurate weight, reconstructed weights were used from samples collected of common species (e.g., bluegill, yellow perch) or from length-weight equations in the literature (Carlander 1969, Carlander 1977). Food habit information was summarized by prey species and size, percent total number, percent weight, and frequency of occurrence. While each of these measures describe an independent component of diet, they each have their limitations and biases (MacDonald and Green 1983). The Relative Importance (RI) index developed by George and Hadley (1979) balances the combined effects of traditional measures of food habits (frequency, weight, and numbers). The RI index represents a mean of these 3 diet measures for each category (Wallace 1981). The index is as follows:

$$RI_a = 100 \text{ X } AI_a \Big/ \sum_{a=1}^{n} AI_a$$

where: n = number of different food types,

AI_a = absolute importance of prey taxa in the diet,

$= \%F_a a + \%N_a a + \%W_a$

where:

$\%F_a$ = percent frequency of occurrence of taxa '*a*',

$\%N_a$ = percent of total number of organisms taxa '*a*',

$\%W_a$ = percent of total weight of food organisms represented by taxa '*a*'.

RI index values range from 0 to 100, with the sum of all *RI* values for the prey taxa equal to 100.

Diet overlap between northern pike can give an indication of competition for food resources. To measure diet overlap between size groups of northern pike the Percent Resource Overlap Index (PROI) was used (Schoener 1970). The index is as follows:

$$\text{PROI} = 100 \left(1 - \left[0.5 \sum_{i=1}^{n} :Px(i) - Py(i):\right]\right)$$

where: n = number of food categories,

$Px(i)$ = mean proportion of food category i in the diet of length group x, and

$Py(i)$ = mean proportion of food category i in the diet of length group y.

PROI values range from 0 to 100, with 0 indicating no diet overlap between length groups x and y, and 100 indicating complete diet overlap between length groups x and y.

Largon Lake

The northern pike population in Largon Lake was sampled during the spawning period in 1990, 1991, and 1992 using fyke nets to estimate abundance and monitor growth response of transferred fish. All northern pike removed from Island Lake and field transferred to Largon Lake were individually marked with anchor tags. Length, weight, sex, and disease information was recorded as described above. Northern pike abundance in Largon Lake was estimated using the Darroch's maximum-likelihood estimator (Everhart and Youngs 1981) during the spring spawning period. This procedure was used because electroshocking was not efficient in capturing fish in Largon Lake.

Abundance of Other Species

Abundance of walleye (≥9 inches) and adult white sucker in Island Lake was estimated using the Bailey modification of the Peterson formula (Ricker 1975). Fish captured during the spring spawning period with fyke nets made up the marking period, and electroshocking shortly after spawning made up the recapture period.

Relative abundance of the white sucker year class during 1985-91 was determined from shoreline seine catches. Seine hauls were made once a month from May through August at 7 stations with a 50-ft X 6-ft seine with 3/16-inch mesh.

Relative abundance of prey fishes in both Island and Largon lakes were assessed with gill nets. Gill nets were fished once a month from May through August during daylight hours for a minimum of 3 hours. On each sampling date 3 150-ft gangs consisting of 50-ft sections of each of 3 mesh sizes (0.8 inch, 1.0 inch, and 1.5-inch stretch measure) were set. Location of gill net sets was randomly determined for littoral areas (<15 ft) with a lake map. Gill net catches were standardized for 450 ft/8 hours.

Results

Northern Pike Response

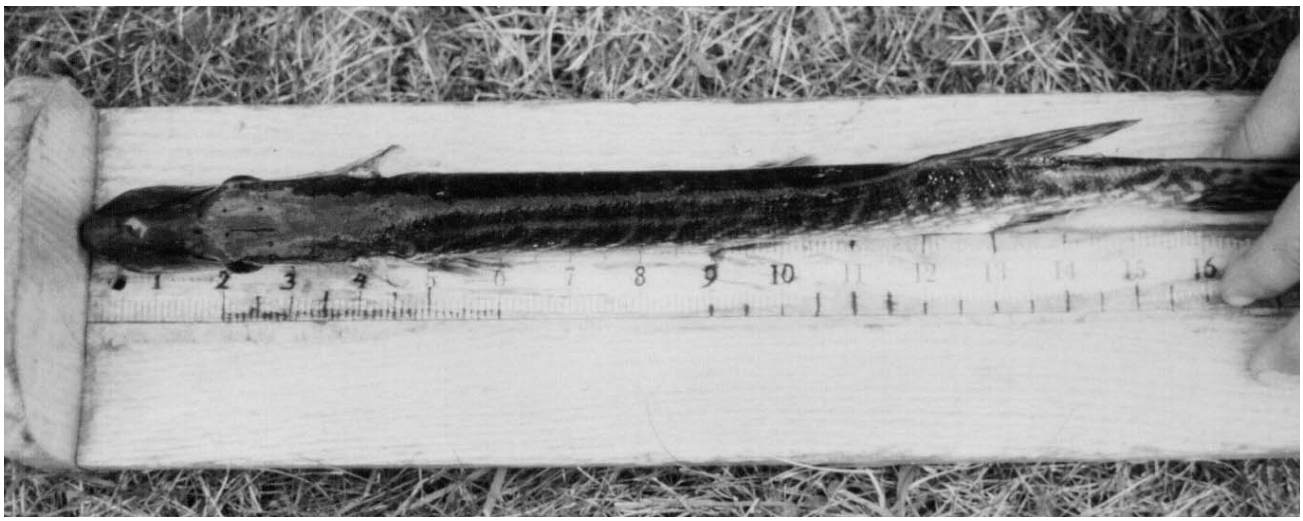
Size Structure

The population size structure of northern pike in Island Lake changed during the period 1985-92. Size structure shifts from year to year were gradual; however, over the study period these subtle changes resulted in a significant decrease in size structure (1985 versus 1992, $P < 0.001$, Kolmogorov-Smirnov test) (Fig. 2).

Changes in mean and median length, and Relative Stock Density (RSD-18) of northern pike also decreased during 1985-92 (Table 2). Mean length of northern pike sampled decreased significantly from 16.3 inches to 14.9 inches ($P < 0.01$, *t* test). Similarly RSD-18 showed a precipitous decline, with 1985 differing from other years ($P < 0.001$, chi-squared test).

Mortality Rates

Total mortality rates were variable from 1985 through 1992. Mean total mortality was 60%



T. MARGENAU

Size, growth, and relative weight of northern pike in Island Lake did not improve following community manipulations.

Table 2. *Characteristics of Island Lake northern pike, 1985-92.*

Year	Sample Size (*N*)	Mean length (inches) (standard deviation)	Median length (inches)	RSD-18[a]
1985	347	16.3 (2.8)	16	26
1986	598	15.8 (2.2)	15	15
1987	656	15.9 (2.3)	15	14
1988	333	15.7 (2.6)	15	22
1989	142	15.2 (2.3)	15	15
1990	350	14.9 (3.0)	14	14
1991	186	14.6 (3.2)	14	12
1992	400	14.9 (2.7)	14	14

[a] Relative Stock Density-18 = (number ≥ 18/number ≥ 14) X 100.

Table 3. *Mean length-at-age and 95% confidence interval (parenthesis) for Island Lake northern pike before community manipulations (pre-treatment, 1986-87) and after manipulations (post-treatment, 1991-92).*

		Sampling Period	
Age	Number	Pre-Treatment	Post-Treatment
2	35	12.5 (12.0-13.1)	
	67		12.9 (12.6-13.2)
3	80	14.5 (14.1-14.9)	
	109		14.7 (14.4-14.9)
4	116	16.3 (15.9-16.7)	
	57		16.7 (16.1-17.2)
5	80	17.7 (17.3-18.1)	
	24		18.6 (17.0-20.1)

Table 4. *Percent number, percent frequency occurrence, percent weight, and Relative Importance (RI) values for major food items sampled from northern pike 1985-90, Island Lake, Washburn County (total items sampled N=742).*

	Percent			
Prey Item	Number	Occurrence	Weight	RI
Bluegill	25.9	33.8	38.3	32.2
Brook silverside	24.5	12.5	5.0	13.8
Northern pike	2.6	3.8	34.4	13.4
Yellow perch	14.4	18.4	4.9	12.4
Cyprinid minnows	9.7	11.9	1.7	7.6
Darters	10.6	9.7	0.9	7.0
Largemouth bass	2.8	4.0	4.4	3.7
Walleye	3.2	2.2	5.5	3.6

Table 5. *Diet overlap of Island Lake northern pike length groups represented by the PROI[a] index, 1987.*

Length Groups Compared	Total Number of Food Items	PROI
9.0-11.9 to	72	64.5
12.0-14.9	173	
12.0-14.9 to	173	82.9
15.0-17.9	155	
15.0-17.9 to	155	56.2
18.0-20.9	28	
18.0-20.9 to	28	29.2
21.0-23.9	5	

[a]Percent Resource Overlap Index.

(*N* = 7 years). The highest calculated mortality rate of 71% in 1986 was followed by the lowest rate of 44% in 1987.

Voluntary tag returns of individually marked northern pike in 1985 and 1986 suggested angler harvest was low. Tag return rates in 1985 and 1986 were 1.7% and 0.7%, respectively. While voluntary returns represent minimum estimates for angler mortality, these numbers suggest most mortality was the result of natural causes.

Relative Weight

Relative weight (W_r) for northern pike decreased following 1986 and then remained similar for 1987, 1991, and 1992. Mean W_r for 1986 was 80 (*N* = 175) compared to 73 (*N* = 184) for 1987, 71 (*N* = 157) for 1991, and 74 (*N* = 111) for 1992. Comparisons of length groups for each year indicated a significant difference between 1986 and the other years ($P < 0.05$, *t* test).

Population Abundance

Abundance of northern pike ≥14 inches in Island Lake declined between 1986 and 1992. Population and density estimates for 1986 were 3,362 (95% C.I. = 2,120-4,604) and 12.2 fish/surface acre, respectively. Population and density estimates for 1987 were 3,244 (95% C.I. = 2,160-4,328) and 11.8 fish/surface acre, respectively. Population and density estimates for 1992 were 1,410 (95% C.I. = 1,007-1,813) and 5.1 fish/surface acre, respectively. The 1992 estimate represented a 57% decline in numbers from 1986 and 1987.

Growth

Growth of northern pike in Island Lake did not improve during this study. Mean length-at-age showed a slight increase during the post-treatment period (1991-92),

however, length-at-age analysis indicated no significant difference between pre- and post-treatment periods for ages 2 through 5 (ANOVA, all $P > 0.2$) (Table 3). Mean length at age 5 was 17.7 inches during the pre-treatment period compared to 18.6 inches during the post-treatment.

Diet

A total of 1,655 northern pike stomach contents was sampled during 1986-90, of which 70.1% were empty. Bluegill was the most important food item as indicated by the RI index (Table 4). Other species of importance included brook silverside (*Labidesthes sicculus*), yellow perch (*Perca flavescens*) and darters (*Etheostoma* spp.); however, their contribution to the northern pike diet differed. Brook silverside were seasonally abundant during fall (Fig. 3) and made up a large percent of the total numbers, but were much less significant in terms of weight. Conversely, cannibalism by northern pike made up a considerable percent (34.4%) of the total weight of food items even though percent number and occurrence were low.

Prey item size remained very similar for different northern pike size groups until reaching 21 inches (Fig. 4). Mean prey size of 9 to 20.9-inch northern pike was <3 inches. Mean size of prey items for northern pike ≥21-inches was 7.8 inches and reflected the observed cannibalism. Plotted 80% C.I. of the mean prey size (Fig. 4) indicated the diet breath of fish <21 inches was limited, whereas fish ≥21 inches utilized some larger items but still ate small items.

Diet overlap between northern pike was considerable, especially where northern pike abundance was greatest. PROI index values calculated using all food items sampled in 1987 ranged up to 82.9 for fish 12-14.9 inches compared to 15-17.9 inches (Table 5). Values >60 are considered biologically significant (Wallace 1981). Diet overlap of northern pike >18 inches decreased (PROI = 29.2), however lower number of food items in these size ranges may have confounded the interpretation.

Field Transfers

Mean length and weight of 615 northern pike transferred from Island to Largon Lake was 14.3 inches (SD = 1.79) and 9.1 oz (SD = 3.35), respectively. Stocking rate of field transferred fish ranged from 1.0-2.5 fish/surface acre.

Population abundance of northern pike in Largon Lake showed little short-term change following the introduction of northern pike from Island Lake. The population of northern pike ≥14 inches was estimated at 228 (95% C.I. = 188-267) in 1990

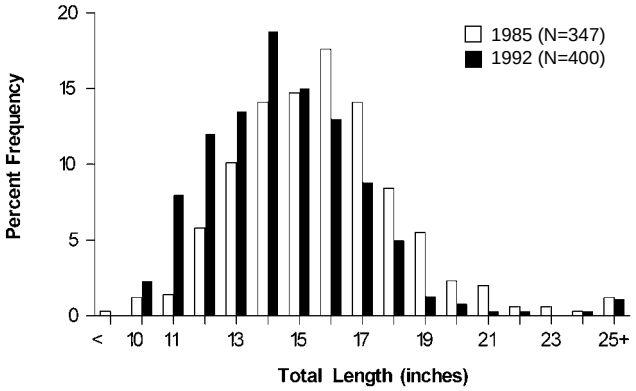


Figure 2. *Length frequency distribution of northern pike length groups in 1985 and 1992, Island Lake, Washburn County.*

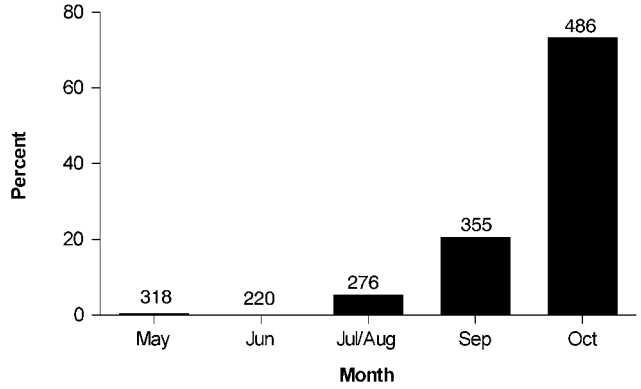


Figure 3. *Seasonal occurrence of brook silverside in stomach contents of Island Lake northern pike, 1985-90. Numbers represent northern pike stomachs sampled. (brook silverside N = 184).*

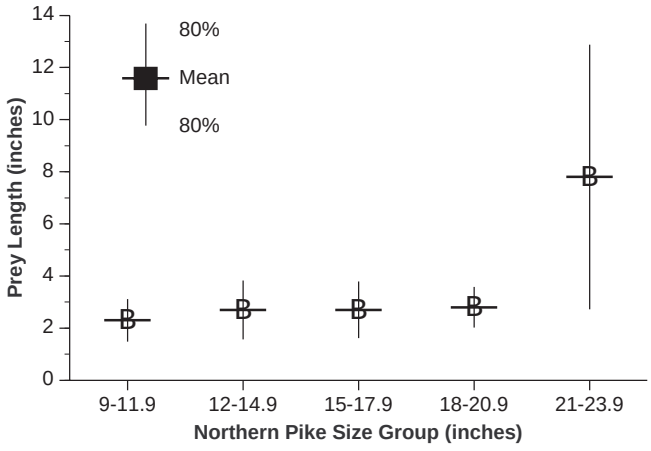


Figure 4. *Mean length and 80% confidence intervals of northern pike food items, Island Lake, Washburn County, 1987.*

compared to 191 (95% C.I. = 165-218) in 1992. Estimated density of northern pike in 1990 and 1992 was 1.8 and 1.5 fish/surface acre, respectively.

Northern pike transferred to Largon Lake were well represented in the overall length frequency distribution by 1992 (Fig. 5). Independent estimates of transferred fish and resident fish indicated transferred fish made up 26% of the total number of adult northern pike in 1992.

Natural recruitment of northern pike appeared to improve following the introductions. In 1990 no resident fish <20 inches were sampled compared to 1992 when untagged (natural) fish were sampled down to 14 inches (Fig. 5).

Growth in length and weight of transferred northern pike was considerable after one year in Largon Lake. Mean length of recaptured individually tagged fish (*N* = 57) following one year at large increased 47% from 14.4 inches (SD = 1.89) to 21.2 inches (SD = 2.52), a mean increase of 6.8 inches. Mean weight of these fish (*N* = 57) after one year increased 301% from 9.9 oz (SD = 3.5) to 39.8 oz (SD = 15.17), a mean increase of 29.8 oz. The incremental increase in length of transferred fish did not differ significantly among ages (*P* = 0.75) or among initial lengths at stocking (*P* = 0.58). However, the mean increment of increased length of transferred northern pike (6.8 inches) was over 3-fold the calculated increment of increase (1.9 inches) for northern pike ages 2 to 5 in Island Lake (1991-92).

Change in relative weight (W_r) of recaptured individually marked fish also indicated an improvement of fish condition one year following transfer. Mean W_r increased from 73.5 to 94.8 (*N* = 57).

Other Species

Walleye

A walleye population was established in Island Lake as a result of stocking. Estimated number of walleye (≥9 inches) in 1992 was 1,032 (95% C.I. 796-1,268) or 3.7/acre. Most fish were <12 inches but ranged up to 24 inches (Fig. 6).

White Suckers

An adult spawning population of white suckers was established in Island Lake by 1992 from the stocking in 1989. Population abundance of adults was estimated at 746 (95% C.I. = 634-858) or 2.7/surface acre. Mean length of these white suckers in 1992 was 17.7 inches (SD = 1.27, N = 414) (Fig. 6).

Seine hauls during the summer months indicated an increase in relative abundance of young-of-the-year (YOY) white sucker in the period 1989-91 compared to 1985-88. Seine haul catches were highest during May and June sampling as YOY became vulnerable to the seine. Mean number of YOY white sucker was 63/haul during May/June 1989-91 compared to 2.8/haul during 1985-88. Seine catches dropped off during July and August to 3.6/haul in 1989-91 and to 0.1/haul during 1985-88. No fingerling white suckers were captured in any seine hauls or gill nets for any years.

Other Prey Species

Gill net catches indicated major forage in Island Lake consisted of small (<4 inches) yellow perch and bluegill (Table 6). Catch of fish >4 inches consisted of low numbers of centrarchid panfish. In contrast, Largon Lake was dominated by fish in the 6- to 8-inch size groups. These consisted primarily of yellow perch, golden shiner (*Notemigonus crysoleucas*), and black crappie (*Pomoxis nigromaculatus*) (Table 6). Mean length of Largon Lake yellow perch captured was 6.8 inches (SD = 0.44) compared to 3.5 inches (SD = 0.43) for Island Lake (Fig. 7).

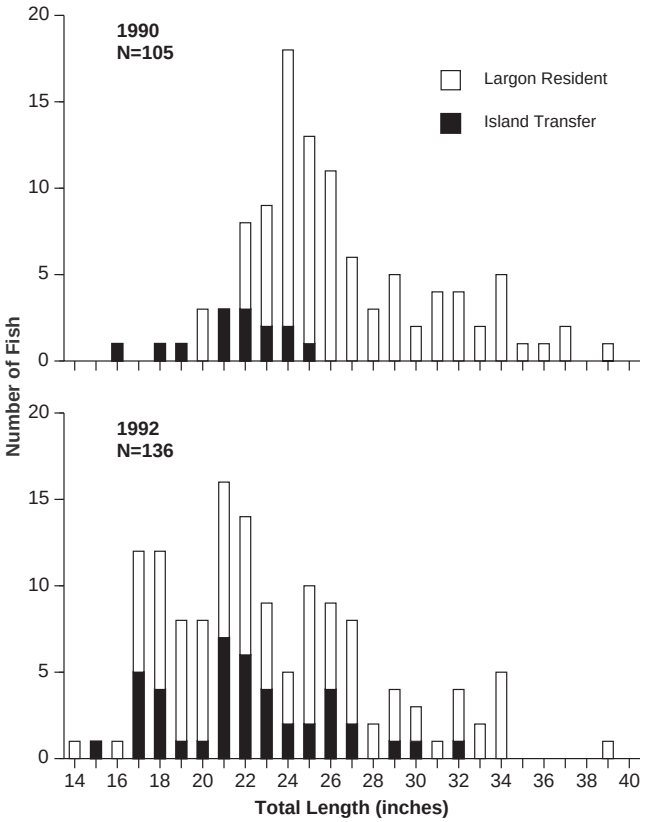


Figure 5. *Length frequency distribution of transferred and resident northern pike sampled in Largon Lake, Polk County, 1990 and 1992.*

Discussion

Community manipulations in Island Lake did not improve the northern pike fishery. Northern pike abundance declined from 1987 to 1992. Size structure, growth, and relative weight all remained similar or decreased.

Population abundance of northern pike ≥14 inches declined by over 50% from the estimated number present in 1987 to 1992. It is not likely that a reduction of this magnitude is the result of removals from Island Lake during 1989-91 as the cumulative total (*N* = 615) for 3 years of removal represents only 32% of the observed reduction. High mortality (mostly natural) and/or year class fluctuations may more likely be responsible for the observed fluctuation in numbers. Annual mortality rates during the study were generally >50% and as high as 71%.

Changes in size structure, growth, and relative weight suggested no direct benefit to the northern pike population from community alterations. This resulted in relatively few fish in the population that could be considered desirable to anglers after the study termination. In 1992, mean length of northern pike was 14.9 inches and only 14% were ≥18 inches. Growth of northern pike was below average and in the lower 10th quantile when compared to growth rates reported by Snow and Sand (1992) for northwestern Wisconsin. In 1992, mean length of a 5-year-old northern pike was 18 inches. Relative weights suggested fish were in poor condition as values ranged from 71-75 for fish 12-16 inches. Willis (1989) suggested W_r values of 86-88 to be indicative of populations with high density and slow growth.

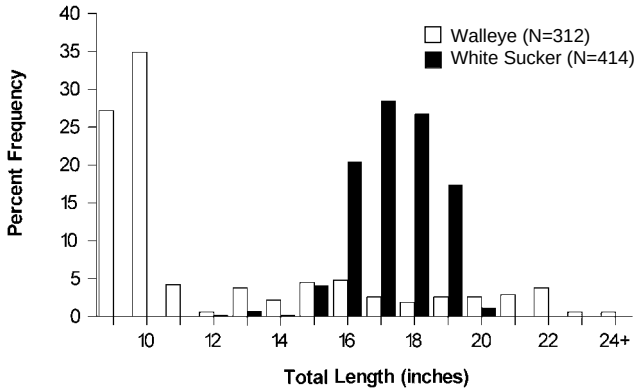


Figure 6. *Length frequency distribution of walleye and white sucker in Island Lake, Washburn County, 1992.*

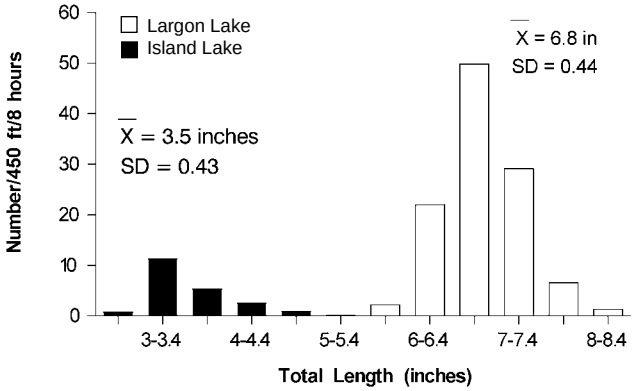


Figure 7. *Standardized gill net catch of yellow perch in Island Lake, Washburn County and Largon Lake, Polk County.*

Table 6. *Gill net catch (number/450 ft/8 hours) of forage fishes in Island Lake (1986, 1987, 1991) and Largon Lake (1990).*

Inch	Island Lake				Largon Lake			
Group	YP	CENT[a]	CYP[b]	Total	YP	CENT[a]	CYP[c]	Total
2	0.7	11.8	0.0	12.5	0.0	0.0	0.0	0.0
3	16.6	8.7	3.8	29.1	0.0	0.0	0.0	0.0
4	3.4	9.0	1.2	13.6	0.0	3.5	0.0	3.5
5	0.1	1.8	0.0	1.9	2.2	6.2	1.8	10.2
6	0.0	3.6	0.0	3.6	71.8	11.4	29.5	112.7
7	0.0	1.5	0.0	1.5	35.7	33.9	23.8	93.4
8	0.0	0.2	0.0	0.2	1.3	1.3	0.9	3.5

YP=yellow perch.
CENT=centrarchids.
CYP=cyprinids.
[a] Includes bluegill, pumpkinseed, and black crappie.
[b] Includes spottail shiner.
[c] Includes golden shiner.

Slow growth and poor condition of Island Lake northern pike are likely symptoms resulting from inappropriate food resources. Northern pike are considered to be opportunistic predators eating the most vulnerable and abundant prey (Frost 1954, Crossman 1962, Mann 1982); however, some studies have demonstrated a preference for soft-rayed and/or fusiform-shaped prey (Beyerle 1971, Mauk and Coble 1971, Wahl and Stein 1988). Diet analysis suggested Island Lake northern pike <21 inches relied primarily on bluegill as prey. Centrarchids are considered an energetically poor forage because of body shape and avoidance behavior (Wahl and Stein 1988, Savino and Stein 1989). Nevertheless, as hunger increases predators generally become less selective in their choice of prey (Emlen 1966, Ware 1972).

Most food items eaten by Island Lake northern pike <21 inches were small (<3 inches), often consisting of bluegill, brook silversides, yellow perch, and darters. Beyerle and Williams (1968) suggested that in waters with small, soft-rayed fishes and few larger fishes, northern pike should grow rapidly to about 15 inches and thereafter grow much more slowly. Diana (1979) suggested that presence of large prey items can have a significant effect on northern pike growth. In Island Lake such larger prey became available to larger northern pike only in the form of smaller northern pike.

If appropriate food was a factor limiting growth and population size structure, then the magnitude of northern pike removal was not adequate to allow greater numbers of prey items per northern pike. Northern pike removals on an annual basis averaged only about 6% of the total number estimated in 1987. Similarly, Goeman and Spencer (1992) were unsuccessful in improving the size structure and growth of northern pike in a Minnesota lake by removing small northern pike. They attributed this failure in part to the inability to remove sufficient numbers of northern pike. During their study, 3-15% of the total number of northern pike were removed. Holling (1973) noted that a major community shift may be necessary to alter community stability. Diana (1987) suggested that reducing food availability by 10% can reduce body weight by over 50% compared to normal rations.

The effect of stocking another predator (walleye) into Island Lake is unknown. Walleye may have provided additional competition for food resources with northern pike and effectively negated any positive effect from northern pike removals. While most walleye were small, larger walleye were well represented in the overall length distribution by 1992 (Fig. 6).

Northern pike transferred from Island Lake to Largon Lake demonstrated improved growth and reached quality sizes. I observed one angler-caught fish in December 1992 measuring 35.0 inches and weighing 11.5 lb. This tagged fish was transferred to Largon Lake from Island Lake in April 1989 at 17.9 inches and 1.1 lb.

After 3 years, field-transferred northern pike made up 26% of the estimated population in Largon Lake; however, population density remained low. Nevertheless, some natural recruitment seemed to occur where natural reproduction was previously nil.

While short-term response of the northern pike population in Largon Lake was positive, long-term and other subtle effects from the transfer need to be monitored. Other components of the fisheries community may serve as important indicators of direct and indirect effects of northern pike introductions (He and Kitchell 1990). At certain densities northern pike can have an impact on species composition and abundance. Johnson (1966) estimated that northern pike consumed 50% of the annual production in a lake. Anderson and Schupp (1986) suggested that a collapse in the yellow perch population in a Minnesota lake resulted from stocking northern pike. Kempinger et al. (1975) attributed a decline in yellow perch numbers in Escanaba Lake, Wisconsin, to the build of northern pike.

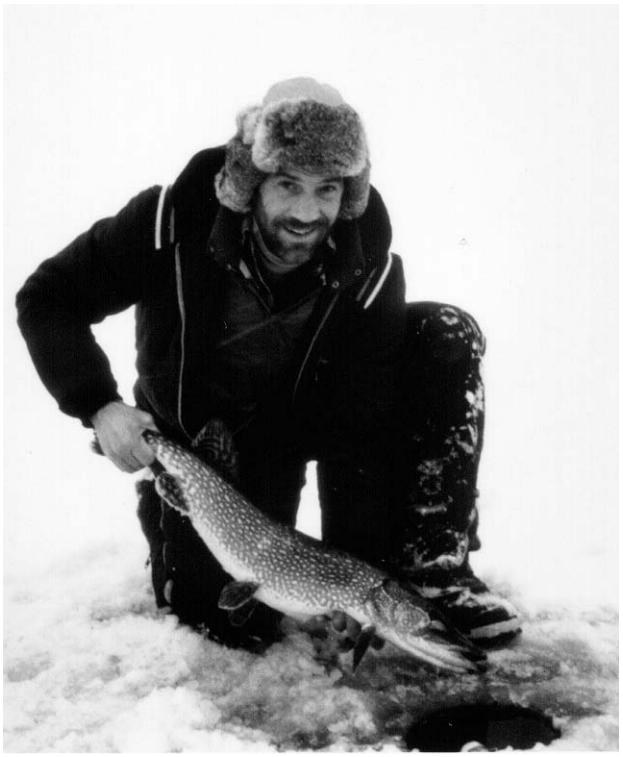
Yellow perch have been identified as an important food item for northern pike in numerous studies (Johnson 1969, Kempinger and Carline 1977, Anderson and Schupp, Treasurer et al. 1992). Yellow perch were more abundant and larger size in Largon Lake compared to Island Lake (Fig. 7). The yellow perch populations in Island and Largon lakes may reflect a response to predation. If the northern pike population in Largon lake were to become too high, the yellow perch population and other components of the aquatic community may be similarly altered. While this study did not focus on response of species such as bullhead and bluegill to alterations, these factors need to be addressed in future studies.

Management Implications

Diana (1987) suggested stunting of northern pike is induced ecologically rather than genetically. Data from this study support this idea. Northern pike in Island Lake failed to respond positively to community alterations; however, it is likely alterations were not intensive enough to have an impact or were in conflict with each other. Conversely, Island Lake fish field- transferred to Largon Lake grew well and reached desirable sizes.

Field transfer of northern pike from stunted populations deserves management consideration or further study. The economic feasibility of this as an effective management tool is unknown. However, biologists and resource agencies need to use discretion regarding the fish source and the receiving water. Introduction of northern pike at high densities can alter community structures and have a negative impact. Disease transfer to a new system is also a consideration. Transfer of fish into different drainages may also disrupt the genetic character of the resident population. These considerations need to be taken into account in forming guidelines for safe and beneficial transfers.

The problem of stunted northern pike in waters dominated by centrarchids is perplexing. It seems ironic a fish with a reputation as a voracious feeder would experience difficulties with growth resulting from inappropriate food. Perhaps northern pike inhabiting these waters are not ecologically capable of reaching large average sizes. Regulations such as minimum size limits have not proven effective (Snow and Beard 1972, Kempinger and Carline 1978) and liberalized regulations to harvest abundant small pike are doomed for failure if anglers choose not to keep the fish (Goeman et al. 1993). Considering the cannibalism occurring by larger northern pike, the concept of a maximum size limit to protect larger fish may merit future investigation. Major community restructuring remains as an option; however, techniques need to be developed to cost-effectively accomplish this objective.



G. LINDENBERGER

Northern pike transferred to Largon Lake grew well and reached sizes desirable to anglers.

Literature Cited

Anderson, D. W. and D. H. Schupp
1986. Fish community responses to northern pike stocking in Horseshoe Lake, Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries Investigational Report 345, St. Paul.

Beyerle, G. B
1971. A study of two northern pike-bluegill populations. Transactions of the American Fisheries Society 100:69-73.

Beyerle, G. B. and J. E. Williams
1968. Some observations of food selectivity by northern pike in aquaria. Transactions of the American Fisheries Society 97:28-31.

Carlander, K. D.
1969. Handbook of freshwater fishery biology. Volume 1. The Iowa State University Press, Ames.
1977. Handbook of freshwater fishery biology. Volume 2. The Iowa State University Press, Ames.

Crossman, E. J.
1962. Predator-prey relationships in pikes (Esocidae). Journal of the Fisheries Research Board of Canada 19:979-980.

Diana, J. S.
1979. The feeding pattern and daily ration of a top carnivore, the northern pike (*Esox lucius*). Canadian Journal of Zoology 57:2,121-2,127.
1987. Simulations of mechanisms causing stunting in northern pike populations. Transactions of the American Fisheries Society 116:612-617.

Emlen, J. M.
1966. The role of time and energy in food preference. The American Naturalist 100:611-617.

Everhart, W. H. and W. D. Youngs
1981. Principles of fishery science. Cornell University Press, Ithaca, New York.

Foster, J. R.
1977. Pulsed gastric lavage: an efficient method of removing the stomach contents of live fish. The Progressive Fish Culturist 39:166-169.

Frost, W. E.
1954. The food of pike, *Esox lucius* L., in Windermere. Journal of Animal Ecology 23:339-360.

Goeman, T. J., P. D. Spencer, and R. B. Pierce
1993. Effectiveness of liberalized bag limits as management tools for altering northern pike population size structure. North American Journal of Fisheries Management 13:621-624.

Goeman, T. J., D. W. Anderson, and D. H. Schupp
1990. Fish community responses to manipulation of yellow perch and walleye abundance. Minnesota Department of Natural Resources Investigational Report 404. 21 pp.

Goeman, T. J. and P. D. Spencer
1992. Fish community responses to manipulation of northern pike and yellow perch densities in a Minnesota centrarchid lake. Minnesota Department of Natural Resources Investigational Report 416. 15 pp.

George, E. L. and W. F. Hadley
1979. Food and habitat partitioning between rock bass (*Ambloplites rupestrisi*) and smallmouth bass (*Micropterus dolomieui*) young of the year. Transactions of the American Fisheries Society 108:253-261.

He, X. and J. F. Kitchell
1990. Direct and indirect effects of predation on a fish community: a whole lake experiment. Transactions of the American Fisheries Society 119:825-835.

Holling, C. S.
1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-23.

Johnson, L.
1966. Consumption of food by the resident population of pike, *Esox lucius*, in Lake Windermere. Journal of the Fisheries Research Board of Canada 23:1,523-1,535.

Johnson, L. D.
1969. Food of angler-caught northern pike in Murphy Flowage. Wisconsin Department of Natural Resources Technical Bulletin 42. 26 pp.

Kempinger, J. J., W. S. Churchill, G. R. Priegel, and L. M. Christenson
1975. Estimate of abundance, harvest and exploitation of the fish population of Escanaba Lake, Wisconsin, 1946-1969. Wisconsin Department of Natural Resources Technical Bulletin 84. 30 pp.

Kempinger, J. J. and R. F. Carline
1978. Changes in population density, growth, and harvest of northern pike in Escanaba Lake after implementation of a 22 inch size limit. Wisconsin Department of Natural Resources Technical Bulletin 104. 15 pp.

MacDonald, J. S. and R. H. Green
1983. Redundancy of variables used to describe importance of prey species in fish diets. Canadian Journal of Fisheries and Aquatic Sciences 40:635-637.

Mauck, W. L. and D. W. Coble
1971. Vulnerability of some fishes to northern pike (*Esox lucius*) predation. Journal of the Fisheries Research Board of Canada 28:957-969.

Mann, R. H. K.
1982. The annual food consumption and prey preferences of pike (*Esox lucius*) in the River Frome, Dorset. Journal of Animal Ecology 51:81-95.

Missouri Department of Conservation
1989. Fishery analysis tools (the "F.A.T" manual): reference and users' guide to FishCalc89 and DisBCal89 microcomputer software packages. Missouri Department of Conservation Division of Fisheries, Jefferson City. 396 pp.

Noble, R. L.
1980. Management of lakes, reservoirs, and ponds. Pages 265-296 *in* R. T. Lackey and L. A. Nielsen, editors. Fisheries management. Wiley, New York.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, 191, Ottawa.

Savino, J. F. and R. A. Stein
1989. Behavioural interactions between fish predators and their prey: effects of plant density. Animal Behaviour 37:311-321.

Schoener, T. W.
1970. Nonsynchronous spatial overlap of lizards in patchy habitats. Ecology 51:408-418.

Snow, H. E. and T. D. Beard
1972. A ten year study of native northern pike in Bucks Lake, Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 56. 20 pp.

Snow, H. E. and C. J. Sand
1992. Comparative growth of eight species of fish in fifty-five northwestern Wisconsin lakes. Wisconsin Department of Natural Resources Research Report 153. 28 pp.

Treasurer, J. W., R. Owen, and E. Bowers
1992. The population dynamics of pike, *Esox lucius*, and perch, *Perca fluviatilus*, in a simple predator-prey system. Environmental Biology of Fishes 34:65-78.

Wahl, D. H. and R. A. Stein
1988. Selective predation by three esocids: the role of prey behavior and morphology. Transactions of the American Fisheries Society 117:142-151.

Wallace, R. K.
1981. An assessment of diet-overlap indexes. Transactions of the American Fisheries Society 110:72-76.

Ware, D. M.
1972. Predation by rainbow trout (*Salmo gairdneri*): the influence of hunger, prey density, and prey size. Journal of the Fisheries Research Board of Canada 29:1,193-1,201.

Willis, D. W.
1989. Proposed standard length-weight equation for northern pike. North American Journal of Fisheries Management 9:203-208.

Acknowledgments

Thanks are due to many individuals during the course of this study. Ron Masterjohn, Don Stafford, Christopher Sand, and Denise Kinderman provided valuable field assistance. John Prohaska, Shannon Fischer, Jeff Kampa, and Tom Fitzgerald assisted with data analysis. Special thanks to Paul Rasmussen, Research Biometrician, for statistical assistance. Paul Cunningham, Martin Jennings, and Michael Staggs provided a critical review of this manuscript. Funding for this study was provided in part by the Federal Aid in Sport Fish Restoration Act, grants F-83-R and F-95-P, and the Wisconsin Department of Natural Resources.

About the Author

Terry L. Margenau is a senior fisheries scientist for the Bureau of Research located at the Northwest District Headquarters, Box 309, Spooner, WI 54801. He began working for the Department of Natural Resources in 1981 with the Bureau of Fisheries Management on Lake Superior. In 1983 he moved to Spooner as a research scientist; his research involves primarily northern pike and muskellunge.

Production Credits

Wendy M. McCown, Managing Editor

William E. Manci, Fisheries Technology Associates, Inc., Copy Editor

Michelle E. Jesko, Layout/Production

Printed on recycled paper.

Wisconsin Department of Natural Resources
PUBL-RS-569 95